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A Modular Solution for Large-Scale Critical Industrial Scheduling Problems with Coupling of Other Optimization Problems

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Abstract : Large-scale critical industrial scheduling problems are based on Resource-Constrained Project Scheduling Problems (RCPSP), that necessitate integration with other optimization problems (e.g., vehicle routing, supply chain, or unique industrial ones), thus requiring practical solutions (i.e., modular, computationally efficient with feasible solutions). To the best of our knowledge, the current industrial state of the art is not addressing this holistic problem. We propose an original modular solution that answers the issues exhibited by the delivery of complex projects. With three interlinked entities (project, task, resources) having their constraints, it uses a greedy heuristic with a dynamic cost function for each task with a situational assessment at each time step. It handles large-scale data and can be easily integrated with other optimization problems, already existing industrial tools and unique constraints as required by the use case. The solution has been tested and validated by domain experts on three use cases: outage management in Nuclear Power Plants (NPPs), planning of future NPP maintenance operation, and application in the defense industry on supply chain and factory relocation. In the first use case, the solution, in addition to the resources' availability and tasks' logical relationships, also integrates several project-specific constraints for outage management, like, handling of resource incompatibility, updating of tasks priorities, pausing tasks in a specific circumstance, and adjusting dynamic unit of resources. With more than 20,000 tasks and multiple constraints, the solution provides a feasible schedule within 10-15 minutes on a standard computer device. This time-effective simulation corresponds with the nature of the problem and requirements of several scenarios (30-40 simulations) before finalizing the schedules. The second use case is a factory relocation project where production lines must be moved to a new site while ensuring the continuity of their production. This generates the challenge of merging job shop scheduling and the RCPSP with location constraints. Our solution allows the automation of the production tasks while considering the rate expectation. The simulation algorithm manages the use and movement of resources and products to respect a given relocation scenario. The last use case establishes a future maintenance operation in an NPP. The project contains complex and hard constraints, like on Finish-Start precedence relationship (i.e., successor tasks have to start immediately after predecessors while respecting all constraints), shareable coactivity for managing workspaces, and requirements of a specific state of "cyclic" resources (they can have multiple states possible with only one at a time) to perform tasks (can require unique combinations of several cyclic resources). Our solution satisfies the requirement of minimization of the state changes of cyclic resources coupled with the makespan minimization. It offers a solution of 80 cyclic resources with 50 incompatibilities between levels in less than a minute. Conclusively, we propose a fast and feasible modular approach to various industrial scheduling problems that were validated by domain experts and compatible with existing industrial tools. This approach can be further enhanced by the use of machine learning techniques on historically repeated tasks to gain further insights for delay risk mitigation measures.

Keywords : deterministic scheduling, optimization coupling, modular scheduling, RCPSP
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